RF Power Amplifier Analysis

Karel Pelikán, Milan Lokay
Department 302
VA Brno
Czech Republic

Abstract

The special program is presented for the demonstration of RF power transistor amplifiers for the purposes of the high-school education in courses of radio transmitters. The program is written in Turbo Pascal 6.0 and enables to study the waveforms in selected points of the amplifier and to draw the trajectories of the working point in a plot of out put transistor characteristics.

1. Introduction

RF transistor power amplifiers represent very significant blocks of up-to-day radio transmitters. They must be studied with the use of the large-signal circuit theory methods, therefore the computer simulation of currents and voltages waveforms is very useful, and it plays an important role in the education process. Transients can be studied with the use of such models in a very convenient way without the dan ger of damaging semiconductor elements if the limiting valu es of transistor parameters are overcome. The simulation re sults can be then verified practically in the laboratory workshop.

There exist sophisticated professional programs (e.g. PSPICE, MICROCAP) for simulation studies of waveforms in electronic devices. Transistors are usually represented in these programs by the well-known Ebers-Moll model. Unfortunately, the parameters of this model cannot be easily determined immediately from catalogue values published currently. The theoretical explanation of the amplifier performance is usually treated in the output characteristics plot of the power transistor. Graphical outputs of professional programs are not fully suitable for the demonstration of power RF amplifiers in the high-school courses. Special program was written therefore for these purposes.

2. Amplifier model

We shall analyze in our contribution the RF bipolar tran sistor amplifier assuming the influence of the inner resistance of the input generator. The analysis is performed in the low frequency region, therefore the parasitic reactance elements and phase shift between the base and collector currents can be neglected. The plot of output collector characteristics is used in our analysis, and the input characteristic is piecewise linear approximated .

The scheme of the discussed amplifier is in Fig.1. The equivalent diagrams suitable for state variable equations are in Fig.2 and Fig.3. The input transformer is assumed ideal with no leakage and with the turns ratio 1:1, so it can be substituted with the primary winding inductance. The feedback between the input and output circuits is neglected.

State variables are denoted Xi following the diagrams in Fig.1 and Fig.2. The differential state equa-

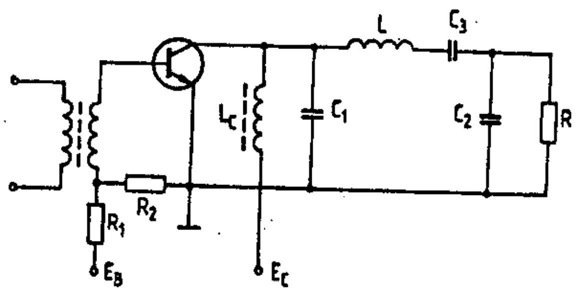

Fig.1
The amplifier scheme

tions can be ea sily obtained directly with the use of elementary Kirchhoff laws as follows

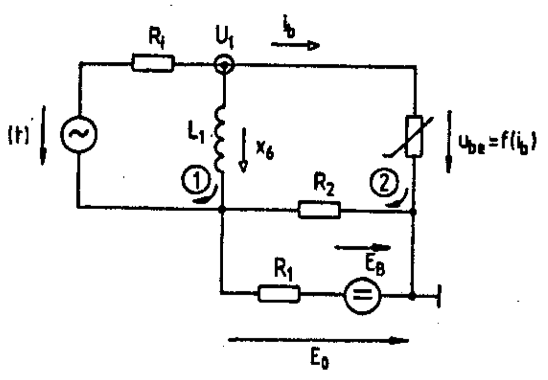

Fig.2
Input circuit equivalent diagram

$$\frac{dx_1}{dt} = \frac{1}{L_C}x_2 - \frac{E_C}{L_C},$$

$$\frac{dx_2}{dt} = -\frac{1}{C_1}x_1 - \frac{1}{C_1}x_3 - \frac{1}{C_1}i(t),$$

$$\frac{dx_3}{dt} = \frac{1}{L}\,x_2 - \frac{1}{L}\,x_4 - \frac{1}{L}\,x_5,$$

$$\frac{dx_4}{dt} = \frac{1}{C_3}\,x_3,$$

$$\frac{dx_5}{dt} = \frac{1}{C_2}\,x_3 - \frac{1}{RC_2}\,x_5,$$

$$\frac{dx_6}{dt} = -\frac{R_i}{L_1}\,x_6 + \frac{1}{L_1}\left(u_1 + R_i\, i_b\right)$$

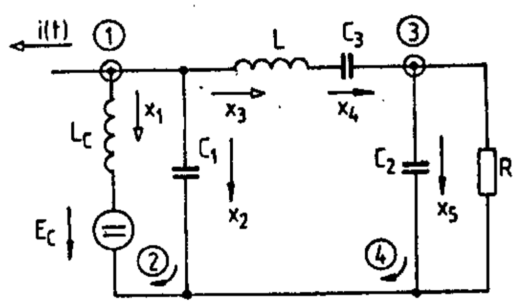

Fig.3
Output circuit equivalent diagram

The base current can be determined with the use of iteration from the nonlinear algebraic equation

$$f\,(i_b) = u_1 - R_i\,x_6 - \left(R_i + \frac{R_1R_2}{R_1+R_2}\right) i_b + \frac{R_2}{R_1+R_2}\,E_B$$

where $u_b = f\,(i_b)$ is the input characteristic of the transistor which is piecewise linear approximated . In our example the influence of the collector voltage on the base current is neglected. The current $i\,(t) = g\,(i_b\,, E_c)$ from the current source is obtained for iterated value of the base current i_b by linear interpolation in the plot of output characteristics. This plot is in the program defined in the form of a table which contains collector current values for selected values of the collector voltage E_c and the base current i_b.

3. Waveform simulation

The state variable differential equations were solved numerically with the use of the Runge-Kutta algorithm of the 4-th order for the harmonic input voltage signal following [1]. If the PC computer with the mathematical coprocessor is used, no numerical error problems occur. Obtained waveforms fully coincide with laboratory experience.

Parameters of the analyzed amplifier, dc supply voltages, the amplitude and the frequency of the input voltage can be put into the program in the initialization procedure PARAMETERS. The component values are calculated in the program and used in coefficients of state equations. The working point $(E_c\,, i_b)$ is plotted in the presented example together with the plot of the transistor characteristics. The main parameters of the amplifier may be changed during a program run by pressing appropriate keys on the keyboard. Special procedure PRESS enables interactive changes of the parameters. Therefore transient states of the analyzed amplifier can be very easily studied, as it documented in Fig.4. The steady state of the so called working characteristic is plotted in Fig.5. The actual time in microseconds is presented in the upper right corner.

The program can be easily modified for plotting of wave forms in all interesting nodes or branches of the amplifier circuits. The program can be successfully used for the two-tone linearity test of an SSB transmitter. The practical program run will be presented.

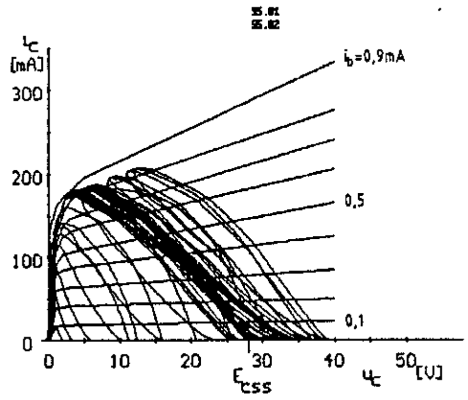

Fig.4
The transient state of the amplifier

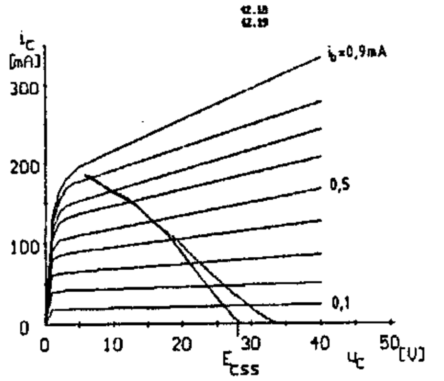

Fig.5
The steady-state working characteristic

4. Conclusion

The presented program was successfully used in our course of radio transmitters. Further application is in the design activities in the area of special radio transmitters.

References

[1] MAYER,D. : Úvod do teorie elektrických obvodů. SNTL/ALFA, Praha 1981.

[2] LOKAY,M. : Příspěvek k analýze vysokofrekvenčních výko nových zesilovačů. CSc thesis, Military academy in Brno, 1992.